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RISK ANALYSIS IN JAKARTA'S WASTE COOKING OIL TO BIODIESEL GREEN SUPPLY CHAIN USING GROUP AHP APPROACH

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Abstract
The Jakarta regulation for waste cooking oil (WCO) shows the desired WCO to Biodiesel supply chain through the DKI Jakarta Governor Regulation Number 167 the Year 2016. Still, the implementation of said regulation proved inefficient. The study aims to analyze the risks in the supply chain because the WCO to Biodiesel supply chain is vulnerable to different risks than the typical supply chain and the green supply chain. The method used in this research is the group analytical hierarchy process (G-AHP) approach to create a consensus model between actors of the supply chain. Deep interviews were conducted with six experts to identify the risks and the normal scale was used to quantify their preference. Then, the PriEst software assisted the risk weight calculation, AHP matrix validation, and consensus modelling. The findings show the supply chain is vulnerable to 23 risks, categorized into six risk categories. The three risks that cause the most uncertainties in the supply chain are supply chain design risk, key supplier risk, and financial source risk. Technology risks and asset failure risks are the least concern because most WCO conversion is not done in Indonesia. These findings would be useful for the government to focus its effort on the most critical risks.

Keywords:
Analytical Hierarchy Process;
Green Supply Chain;
Group AHP;
Risk;
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INTRODUCTION

Waste Cooking Oil (WCO) can cause significant environmental burden and health issues [1][2]. Food safety is especially a concern as WCO gets reprocessed and used in restaurants and animal feed [1][3]. In 2017 Jakarta, Indonesia's capital city was estimated to produce 345.878 liters of WCO per day [4]. It was estimated that 1.889 tons/week of WCO were dumped improperly and reused illegally [5]. Jakarta's government attempted to solve this issue with the DKI Jakarta Governor Regulation Number 167 the Year 2016.

The solution is to convert WCO into Biodiesel. This solution is promising in China, Japan, the US [6][7], Greece [2], Brazil [8], and South Korea [9], which will help Indonesia reach its goal of having 30% bio-content in the Biodiesel by diversifying the feedstock [10]. However, the implementation is not optimal as it is poorly implemented, poorly communicated, and needs revision [1][5]. Many other reasons can cause these efficiencies. In a supply chain. small operational incidents on a stakeholder can have an impact on other actors in the supply chain [11][12].

In view of the above, this study attempts to improve the WCO to Biodiesel supply chain by analyzing the risks in the supply chain. Risk analysis can be challenging due to inaccurate and vague data [11]. The WCO to Biodiesel supply chain is especially complex as it is not only the oil-to-energy supply chain but also a waste management supply chain commonly described as the green supply chain (GSC) [6].

Previous studies analyzed the qualitative risk of the supply chain in Jakarta [5] and nationally [1]. Quantitative analysis using the Analytical Hierarchy Process (AHP) methodology has also been done in Padang [13] and Bogor [14]. These works emphasize Biodiesel and how to improve biodiesel output. It views the supply chain as analogous to the agriculture supply chain. This study, however, emphasizes the waste management aspect and how to reduce WCO from illegal reprocessing, therefore analogous to the GSC.

The analytical hierarchy process (AHP) method is used to combat the data uncertainties and simplify analyzing risk. The AHP is a common technique used in a multi-actor decision-making process that meets the present work's objectives [11][15]. An AHP extension, the group AHP, is then used to construct a consensus model. The first objective is to identify various risks in the supply chain. The second is to weight the risks to understand which risk needs to be prioritized. The result can help the Jakarta government to improve the regulation.

The remaining of this paper is structured as a method that describes the AHP approach. Results and discussion that explores the WCO - Biodiesel supply chain in literature and risks in the supply chain. The result of the AHP and the group AHP calculation for quantitative analysis. The conclusion with a suggestion for the Jakarta government, and finally, the limitations of the present study.

METHOD

This research was conducted using Analytical Hierarchy Process (AHP), a qualitative and quantitative analytical tool. The data was collected through in-depth interviews and questionnaires of six industry experts [16]. The experts consist of one WCO Source, two WCO Collector, one WCO User, an observer, and a regulator. These experts were chosen due to their at least five-year experience, knowledge, and decision-making capability in the WCO-Biodiesel industry. The flow chart of the research is shown in Figure 1.

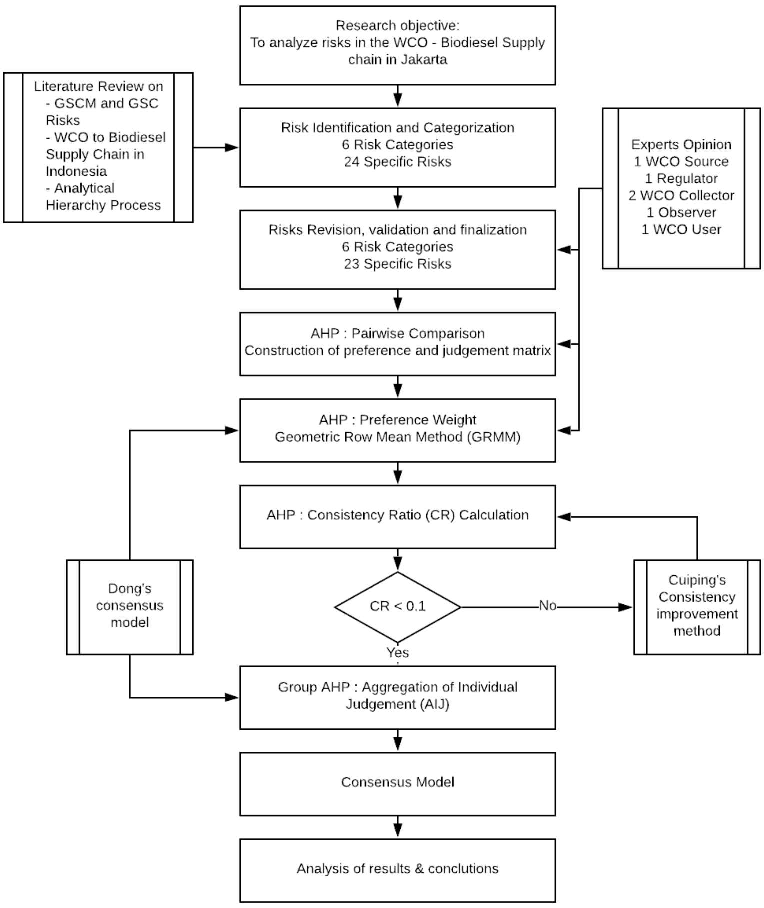

Figure 1. Flow chart of research

Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP) is a tool used to assist in multicriteria decision-making and analyze it. Utilizing relative measurement proved useful to help assess subjective judgment from experts. The tool extends to be a popular tool in risk identification [12, 16, 17] in various industries, including waste management [18].

The AHP is also used to assist in group decisions with diverse evidence by aggregating expert's judgment and priorities. However, AHP is not without criticism as the Fuzzy AHP, another popular AHP extension commonly used in supply chain management, has its validity questioned [15].

Considering the WCO-Biodiesel green supply chain (GSC) in Jakarta is underdeveloped and lacks quantitative data, the AHP methodology using PriEsT open-source software [19] and further group analysis was proposed in this study. Based on Dong's consensus model for the AHP group decision [20], the AHP process is split into six steps.

Step 1: Objective of the study, i.e., to analyze the risks in Jakarta's WCO to Biodiesel supply chain.

Step 2: Risk Identification

Risk Identification was carried out in two steps; first, literature studies of the common risks in the GSC, and then, expert assessment to obtain specific risks in the Waste Cooking Oil (WCO) to Biodiesel Supply Chain.

An initial open-ended questionnaire was formulated through literature reviews. Then, expert discussions were done to correct the questionnaire and identify the supply chain's relevant risks. The questionnaire was revised by removing several irrelevant risks and then given back to the experts. The results were analyzed to validate their opinions, identify risks, and risk priorities as an individual and as a group.

Step 3: Pairwise Comparison

Pairwise comparisons are made by asking experts' preference between two criteria using the fundamental scale. Comparing element, A (X_a) with element B (X_b) will produce a comparison value of X_{ab}. The value of $1/X_{ab}$ is equal to X_{ba}, which is the comparison value of X_b to X_a. The detail of the fundamental scale is shown in Table 1.

Table 1. The fundamental scale for pairwise comparison table [13][18]

Value	Definition	Explanation
1-2	Equal importance	Both risks are equally important
3-4	Moderate importance	One risk is slightly more important than the other
5-6	Strong importance	One risk is moderately more important than the other
7-8	Very strong importance	One risk is strongly more important than the other
9	Extreme importance	One risk is extremely more important than the other

Step 4: Calculation for finding the preference weight.

Preference weight was calculated using the Geometric Row Mean Method (GRMM). Using (1), w_i is the weight of risk *i* and a_{ij} is the comparison matrix between risk *i* and risk *j*. Finally, n is the number of risks in the category.

$$\omega_i = \left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}} / \sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}} \quad (1)$$

Step 5: Check for consistency

It is understood that matrix consistency is seldom possible because of its inherent redundancies [19]. However, it is still a desirable property [15]. The Consistency Ratio (CR) was calculated. The Pairwise Comparison Matrix (PCM) is consistent if the CR is less than 0,1.

$$CR(A) = \frac{\lambda_{max} - n}{(n-1)\cdot RI_n} \quad (2)$$

The consistency ratio of matrix A is affected by its maximum eigenvalue (λ_{max}), the number of compared elements (n) and the Random Index (RI). The values of RI for n 3,4, and 6 are 0.5247, 0.8816, and 1.2479, respectively.

Step 6: Improving consistency

If the PCM is inconsistent, Zeshui and Cuiping's method [21] to improve consistency was used. The method adjusted expert's pairwise comparison to having continuous value. The revised PCM with CR < 0.1 was then presented to experts who validate that the adjusted value does not affect the priority rank.

Step 7: Group AHP consensus model

The AHP for group decision is a method by Dong [20] that was used to construct a consensus model as a tool to help decision-makers reach consensus. A group judgment matrix AG was built using the Aggregation of Individual Judgment (AIJ) method. Group priority preference is derived from the matrix, and the consistency ratio is kept less than 0.1.

RESULTS AND DISCUSSION

WCO-Biodiesel Green Supply Chain

The Waste Cooking Oil (WCO) to Biodiesel supply chain can be viewed from both the feedstock and product aspects [6]. From the product aspect, the supply chain is like other Biomass to Biodiesel supply chains. But, focusing on the feedstock, the supply chain may be considered as a waste recycling supply chain or waste to energy supply chain [3]. Previous studies also show that government involvement in regulation, enforcement, and subsidies is critical to the supply chain.

In Indonesia, the Biodiesel supply chain is well-developed but only with Crude Palm Oil (CPO) as its primary feedstock. The WCO as a feedstock supply chain is underdeveloped, and currently, there is no national or regional level WCO collection system [1]. The Padang and Bogor region understood the potential of WCO and designed a supply chain comparable to an agriculture product supply chain [13][14].

Through the DKI Jakarta Governor Regulation Number 167 the Year 2016, Jakarta has shown its vision of the supply chain. Like Padang, Bogor, and other cities, the main goal is to prevent reprocessed waste cooking oil in food products as gutter oil [1]. It also segmented to supply chain into three major stakeholders: the WCO producers, the collectors, and the users. However, the regulation fails to detail the user's role as a biodiesel enterprise or exporter. Presented in Figure 2 is the WCO Supply Chain in Indonesia, and the outcome desired by the regulation is shown with solid lines.

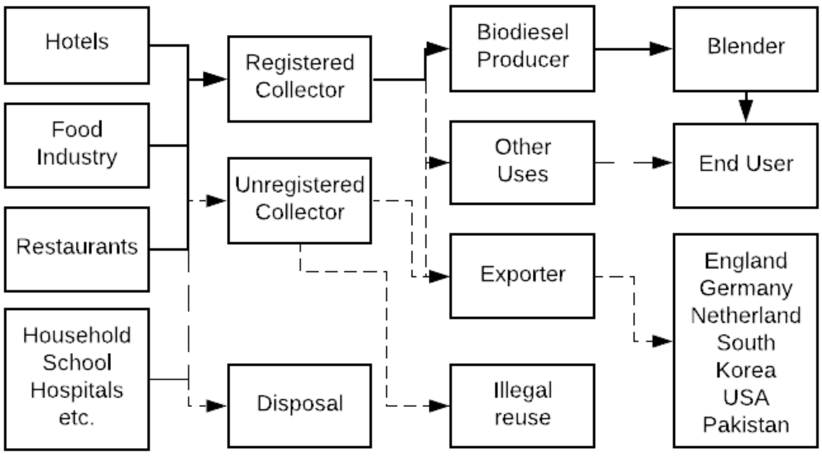

Figure 2. Distribution Flow of Cooking Oil Waste Management in Indonesia

Given the above, the WCO-Biodiesel is not a regular supply chain. Considering DKI Jakarta's regulation's primary goal, the WCO-Biodiesel Supply Chain is a better fit described as a Green Supply Chain (GSC). The word 'green' refers to having the environment as the center for the supply chain discussion. While the biodiesel supply chain is the 'green' diesel supply chain, the WCO-Biodiesel proved to be even more environmentally friendly [22]. With these considerations, the WCO-Biodiesel is a GSC exposed to different or more risks than the typical supply chain.

WCO-Biodiesel GSC Risk

In the typical supply chain, the risk is defined as anything that can happen to disrupt a supply chain and prevent it from working efficiently. Risk should be considered as a multi-faceted phenomenon that could be viewed financially, business continuity, crisis management, or reliability [12]. Specifically, in the GSC, risks are disruptions that affect green materials' movement and eventually affect the environment [11]. Therefore, in the present research work, risk will be understood as events that cause WCO to be reused as gutter oil or disposed to the environment.

Several studies have been conducted on the risks in the GSC and specific risks in the WCO-Biodiesel GSC. These risks also include the risks in the general supply chain. Supply chain risks can be categorized in many ways, but considering previous studies, they were grouped into five categories. The categories are Operational risks (O), Supply risks (S), Product recovery risks (PR), Financial risks (F), Demand risks (D), and Government and Organizational risks (GO) [11]. Further detail can be seen in Table 2.

Based on previous studies, risks in a green supply chain can be categorized into six categories: Operational risks (O), Supply risks (S), Product recovery risks (PR), Financial risks (F), Demand risks (D), and Government and Organizational risks (GO) [6][11]. These categories are further itemized into 24 specific risks. The details can be seen in Table 2.

Table 2. Risk categories and specific risks in the WCO to Biodiesel supply chain

Risks		Description	Source
		Operational Risks (O)	
O1	Asset Failure	Failure of machine, equipment, or facility will reduce supply chain effectiveness	[11][13]
O2	Supply chain design risks	The supply chain is impacted by the flaws in designing the actors, operations, processes, etc.	[11][13]
O3	Labor risk	The scarcity of skilled labor may impact the supply chain	[11]
O4	Technology comprehension risks	Insufficient knowledge of advances, understanding, and availability of WCO to Biodiesel technology will affect the supply chain.	[11][13]
		Supply Risks (S)	
S1	Procurement cost risk	In Indonesia, the price of WCO is higher than CPO, therefore increases the costs at the supplier end.	[11][13]
S2	Key supplier risk	The failure of a supplier, especially major WCO collectors, can stall the supply chain.	[11][13]
S3	Supplier quality risk	Quality problems at the WCO Source's end can cause impacts down the GSC.	[11][13]
		Product Recovery Risks (PR)	
PR1	Reverse logistics design risks	Transportation mode, network design, delivery time uncertainties influence GSC efficiency	[2][11][13]
PR2	Quality Control risks	Failure in screening defective products is detrimental to the GSC.	[2][11][13]
PR3	Take-back Obligation risks	The impact of implementing a take-back obligation will cause supply chain disruption.	[11]
PR4	Capacity design risks	The design of inventory and safety stock capacity of collectors and reprocessing centers impacts GSC efficiency.	[2][11][13]
		Financial Risks (F)	
F1	Financial sourcing	Difficulty in sourcing funds may hinder the adoption of GSC practices.	[11]
F2	Inflation and currency exchange risks	Inflation and currency exchange affect the export rate of WCO and Biodiesel, therefore, influence the GSC	[11]
F3	Financial design restrictions	Lack of financial planning and control can disrupt the GSC.	[11]
		Demand Risks (D)	
D1	Market Dynamics	The perception of the end customer and public impacts WCO biodiesel demand	[11][13]
D2	Key customer failures	Critical customer failures, especially global customer collectors, can stall the supply chain.	[11][13]
D3	Competing risks	Competition in the biodiesel market affects strategy due to the uncertainties of demand for WCO Biodiesel.	[11]
D4	Bullwhip effect	In the typical green supply chain, it is difficult to predict the green product demand. The demand for WCO exports, according to experts, is practically infinite.	[11][13], Rejected by experts.
		Governmental and Organizational Risks (GO)	
GO1	Legal risks	The law, specifically the Jakarta governor regulation, can cause indecisions due to ambiguity.	[11]
GO2	Government policy risks	Incentives may improve the adoption rate of WCO Supply Chain practices.	Added, Industry experts' opinion
GO3	Enforcement failures	The government's failure in enforcing law reduces the supply chain efficiency	Added, Industry experts' opinion
GO4	Organization management risks	These risks represent failures of management policies and plans in the adoption of WCO Supply Chain practices.	[11]
GO5	Partnership risks	Partnerships between members of the WCO Supply Chain can reduce uncertainties	[11][13]
GO6	Information risks	Transparent information pipeline across the supply chain may reduce risk	[11][13]

In the first in-depth interview, experts agreed with the six risk categories. Experts expressed that the bullwhip effect risk is irrelevant. Lastly, they added enforcement failures in the government and organization risk category.

Individual Risk Prioritization

Pairwise comparison was obtained through AHP questionnaires of experts. The values were put into the PriEst software to assist the calculations. Geometric Mean was calculated along with the consistency factors. The risk preference weight is valid if the pairwise comparison is consistent with the Consistency Ratio (CR) below 0.1. If the CR is more than 0.1, a revised matrix is calculated using Zhang's method to correct judgment consistency. The revised matrix was proposed to the expert and repeated until it is accepted. Figure 3 shows the PriEst software.

After individual consistency is accepted, the risk priority for each expert can be analyzed. The priority order of the categories of risks is different for every expert. The operational risk category (O) holds the first rank for WCO Source, but it is ranked 4th by other experts.

Government and Organizational risk categories (GO) are considered significant only by regulators and WCO sources, ranked at most 5th by WCO collector and user. Figure 4 shows a summary of the individual risk category prioritization. Priority for the supply risk category (S) and demand risk category (D) is relatively consistent. It is common for decision-makers to have different opinions as each expert are exposed to different risks and have personal bias. The situation also suggests that actors are working independently [15][20].

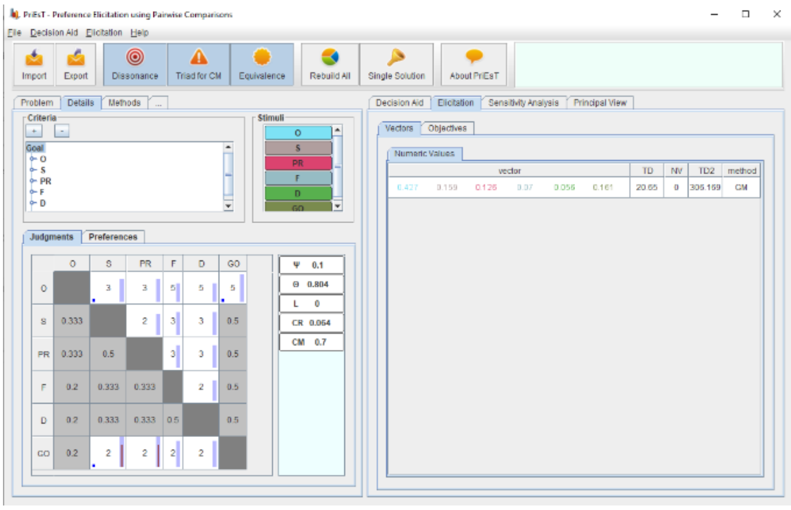

Figure 3. PriEst software

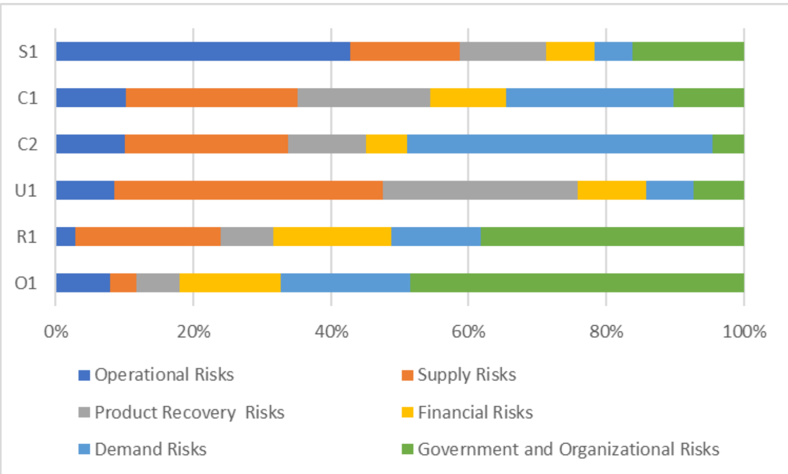

Figure 4. Individual Risk Prioritization

Consensus Model

Once the individual judgment matrices are consistent, preference weights were aggregated using the Aggregated Individual Judgement method (AIJ). The aggregated matrix passed the consistency test with CR < 0.1.

Table 3. Ranking of Risk Category of Consensus Model

Risk Category	Preference Weight	Preference Rank
Operational risks	0.1591	6
Supply risks	0.1754	1
Product recovery risks	0.1677	2
Financial risks	0.1626	5
Demand risks	0.1675	4
Government and Organizational risks	0.1677	3

The aggregated risk priority matrix is consistent with CR < 0.1, so no revision was needed. However, the Geometric Row Mean Method (GRMM) is vulnerable to dissatisfy the Pareto optimally; therefore, group decision might not be well represented. These risk priority preference acts as a guide for stakeholders to reach consensus and be revised periodically.

Analysis of Results

At the categories of risks level, the order of priority is S>PR>GO>D>F>O show in Table 3. The preference weight of categories of risks is used to calculate the global weight preference for specific risks. The global ranking for the specific risks is shown in Table 4, with O2 ranking first and O1 ranking last.

The supply risk category (S) is ranked first compared to other risk categories. In the WCO-Biodiesel supply chain, supply risk is defined as the difficulties and uncertainties in obtaining WCO. Supply is critical to the supply chain as the supply disruption will be felt by all actors [13]. Furthermore, there is a high potential in increasing the supply of WCO as currently, only a small portion is collected [1]. In Padang, supply risk is also ranked first because it has an immediate effect [13]. In this risk, category is procurement cost, supplier failure, and supplier quality globally ranked 5th, 2nd, and 6th.

Supplier failure means that the underperformance of WCO Source will impact the supply chain. It may be caused by a natural disaster such as flooding and the COVID19 epidemic, which heavily impacted the restaurant and hotel industry. Thus, to mitigate this risk, the scope of the WCO source should be broadened.

The product recovery risk category (PR) is ranked second and is defined as the risks related to reverse logistics. Reverse logistics in the GSC is very different from forwarding logistics, as it is more reactive and less visible [23].

Within this category, reverse logistics design risk (PR1) is ranked first. Reverse logistics design consists of the WCO transport route, network size, and location of collection centers. Jakarta's reverse logistics design is underdeveloped as currently, waste centers in Jakarta do not collect WCO despite its capability [5].

Table 4. Preference weight of risks, Group judgment

Risk Cate-gory	Specific risks	Relative preference weight	Relative ranking	Global preference Weight	Global Ranking
O	O1	0.125	4	0.0199	23
	O2	0.504	1	0.0802	1
	O3	0.222	2	0.0353	15
	O4	0.149	3	0.0237	22
S	S1	0.329	2	0.0577	5
	S2	0.348	1	0.0610	2
	S3	0.327	3	0.0574	6
PR	PR1	0.262	1	0.0439	11
	PR2	0.253	2	0.0424	12
	PR3	0.250	3	0.0419	13
	PR4	0.236	4	0.0396	14
F	F1	0.374	1	0.0608	3
	F2	0.293	3	0.0476	10
	F3	0.333	2	0.0541	8
D	D1	0.350	1	0.0586	4
	D2	0.316	3	0.0529	9
	D3	0.335	2	0.0561	7
GO	GO1	0.173	2	0.0290	17
	GO2	0.172	3	0.0288	18
	GO3	0.176	1	0.0295	16
	GO4	0.167	4	0.0280	19
	GO5	0.162	5	0.0272	20
	GO6	0.150	6	0.0252	21

Additionally, the unrecorded community organized waste center and WCO collectors complicate the network design process. Gatekeeping failures (PR2) are ranked lower because WCO quality is less concerned since all WCO will need to undergo a pretreatment process [13]. Inventory and capacity design risk is ranked last because a special container is not required for WCO.

The Government and Organizational risk category (GO) are ranked third. Government risks are ranked higher than organizational risks. Zhang [3] finds that the government's recycling mode affects the recycling rate and profitability. Enforcement failure risk is ranked first because the DKI Jakarta Governor Regulation Number 167 the Year 2016 has not been enforced [1][5] and caused uncertainties. Legal risk is ranked higher than incentive risk because of uncertainties caused by the lack of national-level WCO regulation.

The Demand risk category (D) is ranked fourth as demand has been consistent. To avoid illegal use of the collected WCO, Biodiesel demand is crucial. The global awareness of Biodiesel and WCO creates stable demand for WCO collectors exporting to England, Germany, Netherland, South Korea, the USA, and Pakistan [1]. The demand risk category's importance is expected to change if the supply chain is less reliant on the international market. Market dynamic risks (D1) is ranked first locally and fourth globally. The market changes, along with the resources and preference [11]. Experts suggest more risks in the national market since Indonesians are aware of the dangers of gutter cooking oil.

The Financial risk category (F) is ranked fifth. Finance is crucial as various activities since financial aid and incentive are expected in the WCO supply chain [3][24]. The funding source is ranked first locally and third globally. Experts suggest that more WCO to Biodiesel pilot program is required, and it is challenging to fund. Inflation and currency exchange rates (F2) are ranked last, which means that WCO exports are not affected by it.

The Operational risk category (O) is ranked last. The asset failure category (O1), scarcity of labor (O3), and green technology knowledge (O4) are less critical in this category and globally. This result is atypical because, generally, operational risk is highly prioritized [11][25]. Operational risk in the WCO – Biodiesel supply chain is related to the conversion process. Currently, collected WCO is exported and processed abroad, which reduces the risk for local GSC actors. The operational risk category's importance is expected to change if WCO processing is done locally and the Indonesian biodiesel producer increases their productivity. An improvement to the current supply chain design is required since Bogor's biodiesel program halted in 2015 due to an improper pretreatment process [1]. Thus, supply chain design risk (O2) is ranked first in the category and global ranking.

CONCLUSION

This research shows that the Waste Cooking Oil (WCO) to Biodiesel supply chain in Jakarta is vulnerable to 23 risks and categorized them into six categories. The order of risk categories that should be prioritized are supply risks, product recovery risks, government and organizational risks, demand risks, financial risks, and operational risks. The specific risks with the highest preference weight are supply chain design risk, key supplier risk, and financial source risk. Supply chain design risk is ranked highest because the current methodology of processing WCO to Biodiesel is imperfect, demonstrated by the failed pilot projects. Key supplier risk is ranked second because there are uncertainties in the quantity of WCO caused by the lack of suppliers. Financial source risk is ranked third because it is difficult to adopt the GSC practices without proper financial support.

Jakarta's government should use this study's result to improve its regulation, and risks with a high priority index should be addressed immediately. The primary issue is to finalize the supply chain design, namely deciding to process WCO to Biodiesel nationally or export WCO. The shift to process WCO nationally will heavily disrupt the supply chain. Next is to combat supply inconsistencies by broadening the scope of the WCO source. As the supply chain develops, risk in the supply chain will change. New risks may not have been identified, and interdependencies between risks should be considered. Further study using NGT, Delphi, TOPSIS, or Interval AHP should be conducted. In the end, the result of this research should not be extended to other oil to energy supply chains since the main goal of the WCO supply chain is to reduce WCO misuse.

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